At the date of the last report the measurement of the plates was completed from December 64° to 69°; and in Zone 70° from R.A. 0h. to 13h. 48m. During this year Zone 70° has been finished and Zones 71° and 72° have been measured, with the exception of thirty-six quarter plates. Subject to this exception, the measurement is complete from December 64° to 73°.

Good progress has been made with the printing of the measures. Zone 64° is finished and Zone 65° as far as R.A. 21h. 36m. It is estimated that all the measures from December 64° to December 72° will be included in one volume of about 650 pages.

HELIOGRAPHIC OBSERVATIONS.

In the year ending 1900 May 10, photographs of the sun have been taken on 180 days, either with the Thompson or Dallmeyer photo-heliographs. The former, mounted on the Thompson 26-inch refractor, was used as the regular instrument for solar photography up to March 9, when it was temporarily dismounted, the Dallmeyer photo-heliograph being substituted for it. Of the photographs taken with either instrument, 369 have been selected for preservation, besides 11 photographs with double images of the sun, for determination of zero of position angle. Photographs to supplement the Greenwich series have been received from India or Mauritius up to 1900 March 8.

For the year 1899, Greenwich photographs have been selected for measurement on 202 days, and photographs from India and Mauritius (filling up gaps in the series) on 162 days, making a total of 364 days out of 365 on which photographs are at present available.

The chief characteristic of the sun's surface, during the period covered by this report, has been the steady decline in the mean daily number and area of spots observed, August and September 1899 in particular showing a marked sub-minimum.

MAGNETIC OBSERVATIONS.

The variations of magnetic declination, horizontal force, and vertical force, and of earth currents have been registered photographically, and accompanying eye observations of absolute declination, horizontal force and dip have been made as in former years.

The regular observations of magnetic declination have been made since 1899 January 1, in the Magnetic Pavilion, alternating with determinations in the Magnet House (for effect of the iron in the Observatory buildings), the observations in the Magnetic Pavilion being made with a hollow cylindrical magnet mounted in conjunction with the large theodolite.

The determinations of horizontal force and dip have been made with the Gibson deflexion instrument and the Airy dip circle mounted in the new Magnetic Pavilion, since 1898 September.

The principal results for the magnetic elements for 1899 are as follows:—

Mean declination	16° 34′·2 West.
Mean horizontal force ...	3·9947 (in British units).
	1·8419 (in Metric units).
Mean dip (with 3-inch needles)	67° 10′ 13″.

These results depend on observations made in the new Magnetic Pavilion, and are free from any disturbing effect of iron. The correction to the declination, as found in the Magnet House, is − 10′·7, as deduced from the observations made with the new declinometer in the Magnetic Pavilion.

The magnetic disturbances in 1899 have been few in number. There were no days of great magnetic disturbance and sixteen of lesser disturbance. Tracings of the photographic curves for these days, selected in concert with M. Mascart, will be published in the annual volume as usual. The calculation of diurnal inequalities from five typical quiet days in each month has been continued.

The question of the regulations to be enforced for the protection of the Observatory from disturbance of the magnetic registers by electric railways or tramways in the neighbourhood is now under the consideration of the Board of Trade.

METEOROLOGICAL OBSERVATIONS.

Consequent on the changes in connection with the new Observatory buildings, the shed containing the photographic thermometers was moved 15 feet towards the west on May 16 and 17, 1899.

The Kew Committee of the Royal Society has suggested that steps should be taken to assimilate the methods of registration of atmospheric electricity with the Thomson electrometers at Greenwich and Kew, and the question of the modifications to be introduced into the Greenwich electrometer is now under consideration.

The mean temperature for the year 1899 was 50°·7, being 1°·2 above the average for the fifty years, 1841–90.

During the twelve months ending 1900 April 30, the highest temperature in the shade (recorded on the open stand in the Magnetic Pavilion enclosure) was 90°·0, on August 15. The highest temperature recorded in the Stevenson screen in the Observatory grounds was 88°·8 on the same day.

The month of August was exceptionally warm, the mean temperature for the month being 65°·5, which is 3°·9 above the fifty years' average (1841–1890). This high temperature for the month has only been reached before on one occasion in the previous fifty-eight years, viz. in August 1857. The month of November was also exceptionally warm, the mean temperature for the month being 4°·8 above the average.

The lowest temperature of the air recorded in the year was 18°·0, on February 9. There were fifty days during the winter on which the temperature fell below 32°, a number slightly below the average.

The mean daily horizontal movement of the air in the twelve months ending 1900 April 30 was 268 miles, which is 13 miles below the average for the preceding thirty-two years. The greatest recorded daily movement was 776 miles on April 13, and the least 50 miles on October 22. The greatest recorded pressure of the wind was 27 lbs. on the square foot, on November 3, and the greatest hourly velocity 48 miles, on April 13.

The number of hours of bright sunshine recorded during the twelve months ending 1900 April 30, by the Campbell-Stokes instrument, was 1636 out of the 4454 hours during which the sun was above the horizon, so that the mean proportion of sunshine for the year was 0·367, constant sunshine being represented by 1.

The rainfall for the year ending 1900 April 30 was 21·97 inches, being 2·57 inches less than the average of fifty years. The number of rainy days was 146. The rainfall in the month of August was only 0·354 inch, being the smallest August rainfall on record in the fifty-nine years, 1841–99. The next smallest value was 0·45 inch, in August 1849. The rainfall in February amounted to 3·58 inches, being the largest February rainfall on record in the sixty years, 1841–1900, with the exception of the February rainfalls in 1866 and 1879, which amounted to 4·03 and 3·81 inches respectively.

The remaining portion of the report is devoted to the progress in the printing and distribution of the publications and chronometers, time-signals, longitude operations, &c.

In view of the large additions to and modifications in the instruments and buildings of the Royal Observatory in recent years, it is proposed to prepare a full description of the Observatory, illustrated by photographs.

It may be mentioned that the Observatory equipped and sent out an expedition to observe the total solar eclipse of May 28, having received the sanction of the Admiralty. The Astronomer Royal, with Mr. Dyson and Mr. Davidson, left for Ovar, in Portugal, on May 11, taking with them the Thompson 9-inch photographic telescope, the new 4-inch enlarging lens for large-scale photographs of the corona, a pair of photographic spectroscopes with heliostat, lent by Captain Hills, for photographing the spectrum of the lower chromosphere and of the corona, and a double camera, on one of the photo-heliograph mountings, with lenses of 4 inches and 2½ inches aperture for photographing the coronal streamers.

An examination of the fine photographs that were obtained by the party, which were shown on the day of the visitation, gave one a good idea of the success which had rewarded their efforts.

THE GEOLOGICAL AGE OF THE EARTH.[1]

WHILE, in his efforts to arrive at an estimate of geological time, the geologist himself is seriously hampered by the uncertainty of the data at his disposal, he has followed with expectant interest the successive attempts made by votaries of

1 "An Estimate of the Geological Age of the Earth." By J. Joly M.A., D.Sc., F.R.S., Hon. Sec. Royal Dublin Society; Professor of Geology and Mineralogy in the University of Dublin. Pp. 44. (*Scientific Transactions* of the Royal Dublin Society, vol. vii. Ser. ii. Dublin, 1899.)

kindred sciences to attain the solution of a problem so fascinating. It is true that past efforts in this direction have taught us to expect at the best a merely approximate result, by whatever method this problem may be attacked; at the same time, every attempt is welcome which shall tend to more narrowly limit the margin of approximation. In the important treatise before us, Prof. Joly proposes a novel and ingenious method of approaching this difficult question, and if his argument relies for its success on a considerable basis of assumption, he has nevertheless arrived at results of striking interest.

It is, first of all, assumed that the denudation by solution of the land surface, since the first formation of a solid earth-crust, has been on the whole a uniform process; and further, that the amount of sodium now contained in the ocean has been for the most part transported to it by rivers since the land surface first became exposed to the action of solvent denudation. The reasons which, in the author's view, render these assumptions probable truths are fully discussed in the paper. If, now, we can obtain a correct estimate of the amount of sodium at present contained in the waters of the ocean, and also of the amount annually supplied to the latter by rivers, we have the requisite data whereby the earth's geological age may be determined. Basing his calculations upon the most careful and recent estimates, Prof. Joly finds that the mass of sodium contained in the ocean amounts to $15,627 \times 10^{12}$ tons. In estimating the amount of sodium carried annually by rivers into the sea, Sir John Murray's analyses of nineteen rivers (including many principal ones) are quoted, and a result of 24,106 tons of sodium per cubic mile of river water is obtained. Sir John Murray's estimate of the annual river discharge into the ocean, amounting to 6,524 cubic miles, is also accepted. From these figures the mass of sodium annually carried to the sea is calculated, and this amount divided into the total mass of sodium contained in the ocean, gives a result of about 94,800,000 years, representing the duration of geological denudation. So much is set forth in the first section of the paper. In the succeeding eight sections corrections on the above estimate are discussed, and several possible objections are dealt with.

The author first enters into a speculative discussion regarding the succession of events attendant on the first cooling of the earth's surface, with the object of arriving at conclusions as to the nature of the primitive ocean. Incidentally the view is favoured which supposes that at the first condensation of water upon the surface a greater density was conferred on the sub-oceanic crust than on the sub-aërial tracts; it is deemed improbable that this distribution of pressure became subsequently seriously modified, and the author gives his support to a belief in the permanency of ocean basins. The early ocean itself is supposed "for want of other known alternative," to have contained "a quantity of hydrochloric acid roughly represented by the chlorine now in the ocean." This being admitted, it is clear that a certain degree of saltness would primarily be acquired by the early hydrosphere, and this must be allowed for in modifying the above estimate of geological time. To accomplish this Prof. Joly first quotes Clarke's average analysis, showing the probable composition of the primitive earth-crust. The action of the heated acid ocean upon such a rock mass, and the apportioning of the acid among the bases, is next considered. It is calculated that of the total amount of chlorine contained in the original ocean, only 14 per cent. could have been taken up to form sodium chloride, and in order to arrive at the actual amount of this first formed sodium chloride, Prof. Joly proceeds to estimate the chlorine of the original ocean. This is done by subtracting from the total amount of chlorine now contained in the ocean the quantity of that element supposed to have been transported to it by rivers during the course of geological time. But of the river-transported chlorine a certain proportion has been derived from the sea itself, and for this a deductive allowance of 10 per cent. is made as probably sufficient. Having estimated that a total of about 76×10^6 tons of chlorine are annually supplied by rivers to the sea, the author *assumes* the duration of geological denudation to have been about 86×10^6 years, and finds that during this period 6536×10^{12} tons of chlorine have been introduced into the ocean. By subtracting this from the total chlorine now contained in the sea (as sodium chloride and magnesium chloride), a total of $21,780 \times 10^{12}$ tons is arrived at, representing the original chlorine of the oceanic waters. If 14 per cent. of this would unite with sodium, then 1972×10^{12} tons of sodium were brought into solution by the action of the primitive acid ocean. This result can now be employed in correcting the original estimate of geological time, which was reckoned on the supposition that all the sodium now in the ocean had been supplied by rivers. Thus, the total amount of sodium supplied by rivers is reduced to $13,655 \times 10^{12}$ tons, and this deductive correction of 12·6 per cent. reduces the duration of geological time to $86·9 \times 10^6$ years. The value of this ingenious correction appears to be lessened, however, by the necessary introduction of an arbitrary assumption for the duration of geological time. Is there any reason, too, to show that at the first condensation of water upon the earth, alkalies may not have been present to neutralise to almost any unknown extent the acid of the primæval ocean? The author believes that the amount of correction necessary in allowing for the action of acids other than hydrochloric, in the primitive ocean, is practically negligible.

By a further slight modification of the figures representing the sodium annually transported into the sea, a final estimate of 89·3,000,000 years is arrived at, a figure based, we are told, "on the most complete estimate of probabilities." But even in this estimate the author does not claim a degree of accuracy "approximating to so small a time interval as 100,000 years."

Prof. Joly then examines the significance of rock-salt deposits, as possessing a possible bearing on his theory, but having discussed the origin of such deposits he concludes that any error involved by ignoring them must be very slight. But the extent of the saline deposits surely cannot possibly be estimated, and may perhaps have been considerably underrated. Even if it be admitted, as urged by the author, that the salt basins of the present day are in great part not of oceanic origin, this does not necessarily apply in like degree to saline deposits of the past, when earth movements may have played a more vigorous part in aiding their formation as oceanic derivatives.

A point of seemingly great significance in its bearing on Prof. Joly's theory is the retention of salts in the interstices of stratified rocks, the salts derived from the waters in which the rocks were laid down. In 1856 Dr. Sorby drew attention to the soluble salts contained in certain dolomites, and Dr. Sterry Hunt has recently referred to the "fossil sea water" retained in the pores of stratified rocks.

The observations of the Rev. O. Fisher on this point, recorded in a recent review of Prof. Joly's paper (*Geol. Mag.*, March 1900) are of the greatest interest, as showing that some of the sodium of river waters may have been derived not from the rocks, but originally from the ocean itself.[1] In estimating the mass of sodium held in solution by the ocean, should not some allowance be made too for an unknown bulk of highly pervious deep-sea sediments? May not such deposits be in part of great thickness, and by reason of the sea water with which they are impregnated form a store for sodium?

In the succeeding section the potash and soda percentages of the igneous and sedimentary rocks respectively are considered. Quoting Clarke and Rosenbusch for estimates of these, Prof. Joly attempts to prove that the deficiency of soda in the sedimentary rocks (1·47 per cent. of soda and 2·49 per cent. of potash, as against 3·61 per cent. of soda and 2·83 per. cent. of potash in the primitive crust) is accounted for by the amount of sodium calculated to have been supplied to the ocean by rivers. It is claimed "that the estimated amount of sedimentary strata would, in its formation, be adequate to yield to the ocean the sodium that is in it, assuming these sedimentaries to be derived from rocks having the mean composition of the important eruptive masses now known." Allowance is made for a slight deficiency in the sodium of the ocean by the existence of the rock-salt deposits. For the success of this argument it is unfortunately necessary to assume that a correct estimate of the total bulk of the sedimentary rocks is possible. Mr. Mellard Reade's calculation is provisionally taken as a basis. Accepting also Mr. Reade's estimate of the proportion of calcareous to other sediments, the latter are found to be equal to a layer 1·6 miles in depth over all the land area. From this the mass of the detrital sediments is calculated, and the actual amount of their soda is arrived at. To this is now added the amount of sodium (reckoned as soda) contained in the sea. This restoration would bring the soda percentage of the total mass of sedimentary rocks, even allowing for the rock-salt deposits, to little above 3 per cent., and in order that the figures shall be brought into better accordance with Clarke's calculated soda percentage for the primitive crust, the estimate of the amount of detrital sedimentary rocks is ingeniously amended to equal a layer 1·1 miles thick over all the land area, with the result that an amount

[1] Since these lines were written, Prof. Joly has dealt further with this point and with the question of alkalies neutralising the primitive acid ocean (*Geol. Mag.*, May 1900).

is obtained little short of the desired 3·61. This result must appear sufficiently striking, but it may be seriously doubted whether even an approximate estimate of the total bulk of sedimentary strata can possibly be arrived at. Such an estimate must inevitably rest in great part on a basis of pure speculation. Not only are we ignorant, as regards huge areas, of the thickness of these strata, but immense tracts still remain unexplored so far as their geology is concerned. Further, the boldest guess can tell us little of sedimentary strata hidden beneath the surface of the ocean, and it may be looked upon as a lucky coincidence that Prof. Joly is able to attain the above result when restoring to the estimated sedimentary rocks the sodium of the sea. The question also of pre-Cambrian rocks of sedimentary origin appears here to be too lightly passed over, for although so little is known of their actual extent, the trend of recent researches has been to show that they may constitute a not unimportant fraction of the total sediments formed. It is scarcely necessary to recall the fact that the earliest known fossil faunas, including marine forms of comparatively high organisation, clearly indicate that a habitable ocean had already for long ages been in existence.

The unequal ratios of the alkalies in the ocean and in the rivers respectively next receive attention. The fact that the ratio of potash to soda is very much higher in the rivers than in the sea, is believed by the author, not to indicate that the rivers now contain more potash relatively to soda than in former times, but is to be accounted for by the constant abstraction of potash from the ocean, largely in the glauconite now forming on the sea floor, and so extensively distributed in the sedimentary strata. Stress is also laid on the fact that potassium brought from the atmosphere by rain tends to become retained upon the land, while the sodium is more readily returned to the ocean. In arguing for the uniformity of denudation by solution in past times, Prof. Joly brings forward some good reasons to show that the distribution of land and sea can have varied but little. As regards the greater exposure of igneous rocks in early times some interesting points on the nature of weathering and soil formation are noted, and it is concluded that the unequal percentage of sodium in the igneous and sedimentary rocks would, as regards supply to the ocean, be counterbalanced by the different rates of weathering. Sedimentary rocks, poorer in alkalies, allow of more rapid denudation.

In the concluding section of this paper the action of the ocean as an agent in solvent denudation is dealt with. Such action, the author maintains, is carried on chiefly along the coast lines, and is very small as compared with that effected by rain and river waters. Experiments are quoted to show that the power of sea-water to decompose felspar is minute in comparison with that exerted by fresh water. It is further pointed out that the volcanic *débris* of oceanic deposits have the alkali ratio of igneous and not that of sedimentary rocks. A correction of half a million years on the original time estimate is thought to be a sufficient allowance to make for the solvent denudation by the ocean. But even allowing, as held by the author, that chlorides other than sodium chloride may in past times have in some measure retarded solvent denudation by the ocean, it may be suggested that subaqueous volcanic action, at one time more frequent than at present, with its attendant conditions of exceptional temperature and pressure, may by frequent repetition through vast periods of time have played some part in aiding this process.

Prof. Joly does well in finally recognising the uncertainty attending his corrections on the original estimate of geological time, and he certainly allows no too wide a margin for error in the final result when he claims that "a period of between eighty and ninety millions of years" has elapsed since the land first became exposed to denuding agencies. For not only in the data upon which the corrections are founded, but also in the factors employed in the original calculation, there is to be found comparatively little of certainty and much that is purely speculative. In this latter category must be placed the supposed sequence of events at the first cooling of the globe. The relative intensity of geological activities in the past is also unknown to us, and the possibilities as regards the activity of the sun and the influence of the moon in modifying meteorological agencies during the earlier chapters of the earth's history appear to render hopeless the final solution of the time-problem by such a method as that here employed. But in this interesting treatise Prof. Joly has with marked ability and originality attacked a most difficult question, and his novel theory calls for the fullest consideration from all geologists and physicists.

NOTES ON SATURN AND HIS MARKINGS.

THE possessors of telescopes will welcome the reappearance of Saturn as a rather conspicuous object in the evening sky. The planet now rises at 7h. 40m. p.m., and remains visible afterwards throughout the night, but unfortunately his altitude is extremely low. His southern declination being 22½°, his position is only 16° above the horizon at Greenwich even at the time of his meridian passage. Notwithstanding these unfavourable conditions, excellent views may, however, occasionally be obtained of his general aspect. From stations in the southern hemisphere the planet may be seen under the best circumstances.

This planet with his rings, belts and moons, forms a picture quite unique of its kind. The globe is greatly compressed at the poles, like that of Jupiter, and the rate of its axial rotation similarly rapid. We recognise also in the dusky bands of Saturn another parallel to the visible lineaments of the "Giant Planet," but there is a marked difference as regards the distinctness with which the details on the two bodies may be viewed. Jupiter's large disc and superior brilliancy enable the markings and their variations of form and motion to be followed with great facility and certainty. Saturn being much smaller and fainter is more difficult, especially as regards the more delicate features. Cassini's division in the rings and the principal belt on the globe may be distinguished with a two inch refractor, but Encke's division in the outer ring is a doubtful, or probably a very variable feature, which at certain times appears to be missing altogether, while on other occasions it is described as faintly outlined as a pencil-like curve at the ansæ.

That there are occasional irregularities on Saturn is proved beyond contention. In 1790 Sir W. Herschel remarked a very dark spot on the limb, and in 1793 noticed some irregularities in a quintuple belt which enabled him to ascertain the planet's rotation period. The large white spot seen by Prof. Hall and others at the close of 1876 affords a good instance of change, and it is well-known that the disposition and number of the belts vary from year to year. We naturally conclude that these belts must occasionally exhibit irregularities like those of Jupiter.

The planet is now presented to us at an angle which permits the ring system to be seen with splendid effect. We now view the northern side of the ball and rings, and this will continue to be the case until 1907.

Perhaps there is no object upon which it is easier to exercise the imagination than upon Saturn. And there is probably no orb in reference to which more errors in detail have been made, though both Mars and Venus have encouraged a large number of observational misconceptions. Many of the abnormal results reported in recent years, and due to small instruments, may be safely dismissed, for they are not only doubtful but, when all the conditions are considered, ridiculous, and palpably the outcome of unconscious suggestions of the imagination. Yet there can be no question as to the good faith of those who are responsible for some of the wonderful seeings lately published. They honestly believe they have seen what they have drawn, and as a matter of fact it is an extremely difficult point to distinguish between real and imaginative features on Saturn. The trembling of the image, its faintness under high power or its smallness under low power encourage much fictitious detail which every observer cannot regard as illusory.

Some of those who claim to have seen many irregular markings on this beautiful planet ascribe their success to special training; but this explanation will scarcely stand, for others of equal experience and using more powerful appliances have quite failed to observe them. The difference is not one of sight, of practice, or of instrumental means. It resolves itself into a question of personal ethics. There are men who will report nothing but what they are absolutely certain is presented to their eyes, and are unbending in their regard for the truth; there are others who, though equally sincere in intention, are not so reliable in their judgment, and accept features which are apparently glimpsed, but which are in reality prompted by the imagination on an unsteady and very delicate object.

It is to be hoped that time will eliminate all the fanciful representations of Saturn which recent observations have so abundantly supplied. The period has now arrived when the planet may be telescopically surveyed with a view to obtain a really sound knowledge of such features as are portrayed in moderately powerful instruments. Those who have employed large and small telescopes in planetary observation aver that the former are more effective than the latter; but it is remarkable